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FINAL REPORT

FIELD SURVEY OF KABULI CHICKPEA AND DRY BEAN PLANT SPACING UNIFORMITY

19990341

Funded by
The Agriculture Development Fund
February 2001

Prepared by: Lloyd Zyla

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AGRICULTURAL ENGINEER

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FINAL REPORT

FIELD SURVEY OF KABULI CHICKPEA AND DRY BEAN PLANT SPACING UNIFORMITY

Project No. 0006
Contract No. 19990341

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Date: December 31, 2000

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SUMMARY

In an effort to reduce capital expenditures, dryland growers of kabuli chickpea and dry bean in Saskatchewan have been seeding their crops with conventional seeding equipment rather than precision planters. Intra-row plant spacing has been non-uniform, and this project was undertaken to quantify that non-uniformity. Data on within-row plant spacing were collected from twenty-nine commercial growers of dry bean and kabuli chickpea in Saskatchewan during the 2000 growing season. Although a comprehensive statistical analysis was not completed, due to uncertainty in target seed rates and emergence values, evaluation of the data in histogram format showed that plant spacing was non-uniform.

TECHNICAL REPORT

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1. Abstract

The optimum sample size for evaluating seed spacing uniformity was determined from the literature to be 250. Therefore, seventy-five spacings in four replications were obtained from each field by marking plant locations on a string held above the plant row. Replicate locations were chosen by judgement to be representative of typical field conditions, and locations with poor emergence were avoided.

Data were collected from twenty-nine commercial fields of dry bean and kabuli chickpea in Saskatchewan, and histograms plotted for each field. Plant spacing patterns were not apparent indicating non-uniformity in spacing. Calculations, based upon a quality of feed index (QFI) were subsequently completed in an attempt to objectively quantify the non-uniformity. QFI values averaged 34 and 37% for the bean and chickpea fields respectively, but were considered unreliable estimators of non-uniformity since seeding rate and percentage emergence were not known with sufficient accuracy.

2. Background and Objectives

A majority of dry bean production in the irrigation district of Saskatchewan is seeded with row-crop precision planters that employ single seed metering technology. Under dryland conditions, dry bean and chickpea is sown with conventional seeders that employ bulk seed metering technology. A possible hindrance to expansion of bean and chickpea production in Saskatchewan is that conventional seeding equipment produces non-uniform spacing of the plants within the seed row. This occurs because the metering systems of conventional seeding equipment are not designed to singulate the seed and drop it at evenly spaced intervals.

Current area production of dry bean in Saskatchewan is approximately 10,000 ha (Dr. Tom Warkentin, Pulse Crop Breeding and Management, Crop Development Centre, University of Saskatchewan) but could potentially reach 650,000 ha (Minogue 1996) with most of this growth occurring under dryland conditions. Chickpea production meanwhile has grown from 10,500 ha in 1997 to 280,000 ha in 2000 (Dr. Tom Warkentin, Pulse Crop Breeding and Management, Crop Development Centre, University of Saskatchewan). Minogue (1996) has estimated that area production could potentially reach 970,000 ha in Saskatchewan. A uniform plant spacing, using conventional seeding equipment, may assist in obtaining the area production potential of these two crops.

Robinson et al. (1982) report that a reduction in row spacing and an accompanying greater uniformity of plant spacing have been a trend for the major cultivated row crops of the north central USA for the last forty years. Saskatchewan growers of dry bean and chickpea have the opportunity to adopt these crops while avoiding the capital cost of row-crop equipment (precision planters). Although the requirement for a uniform plant spacing within the seed row may not be as great for the narrow row spacing of conventional seeding equipment, a low-cost add-on singulator that would minimise the extremes in plant spacing may be beneficial.

The objective of this project is to determine the within-row plant spacing uniformity of ten commercial kabuli chickpea and dry bean production fields in Saskatchewan. The data will be used to quantify the degree of non-uniformity and determine the need for development of a low-cost, add-on singulator for improved seed spacing from conventional seeding equipment.

3. Literature Review

3.1 Effect of plant spacing uniformity on yield and quality

3.1.1 Introduction

A non-uniform plant spacing has the potential to reduce yields when closely spaced plants compete for light, moisture and nutrients. Plants spaced too far apart also have poor utilisation of soil area. Dr. Bert Vandenberg (Pulse Crop Breeding and Management, Crop Development Centre, University of Saskatchewan) conducted preliminary tests in 1999 that showed this to be true for two varieties of pinto bean. Furthermore, a review of the literature revealed similar results for other crops. Wahab (1982) for snap bean pod yield, Davies et al. (1985) for vining pea, Parvez et al. (1989) for soybean, Heege (1993) for field bean, and Krall et al. (1977) for corn are just

some of the examples. It is also commonly recommended that precision planters drop corn seed so that placement is uniform in both depth and spacing (Randall et al. 1985).

3.1.2 Ability to compensate

Many crop types, particularly small grains, have the ability to compensate for variability in plant spacing. For example, a yield advantage was not obtained when spring wheat and durum were seeded on a precise geometric spatial arrangement (Auld et al. 1983). In a soybean study, Wiggans (1939) varied intra-row spacing from 13 to 150 mm, row spacing from 200 to 810 mm, and plant population from 11 to 190 m^{-2} Although yield increased as the arrangement of plants approached a square distribution, it was concluded that soybean plants, like many others, can make wide adjustments to space. Furthermore, it was recommended that optimum rates and plant spacing need to be determined for each variety and location.

3.1.3 Conflicting information

The early recommendations of Wiggins (1939) appear to be applicable to other crops and may explain why the literature reveals conflicting information on the need for uniform spacing. For example, Krall et al. (1977) found that two locations showed a decrease in corn seed yield as variability of spacing increased, while a third field showed no correlation with yield. Halderson (1983), without experimental data, states that certain varieties of edible bean have shown yield advantages when plant spacing within the row was the same as spacing between rows. Although Davies et al. (1985) report a yield advantage for vining pea, the advantage disappeared when the crop matured and was harvested dry. Kahn et al. (1995) found that precision planting did not produce a yield advantage in cowpea. Robinson et al. (1982) reported that yield reductions for uneven plant spacing in sunflower ranged from none to 31% and averaged 10%.

3.1.4 Effect of plant population on yield

Perhaps the greatest factor affecting yield is plant population. Hoff and Mederski (1960) report that equidistant spacing improves yield as corn plant populations increase. Nangju et al. (1975) discovered a highly significant correlation between the log of the yield per plant and the population density. Between-row and within-row densities were virtually independent in their effects, and the former had the greater effect. Heath and Hebblethwaite (1987) report that plant density of combining pea has a greater influence on yield than spatial arrangement for 10 cm rows, and precision drilling will not likely increase yield provided the crop is sown at sufficient density to ensure satisfactory photosynthetic area index during pod fill. Heyns (1989) reports that as long as the seed distribution for maize is reasonable, with no undue drop in seed population, the eventual yield will not be noticeably affected by uneven spacing patterns.

3.1.5 Other reasons for increasing uniformity

Other reasons for increasing plant spacing uniformity might include quality issues such as uniformity of maturity and seed size, a reduced disease pressure, reduced weed growth, and lower seed costs. Uniformity of maturity may also be particularly important for northern latitudes such as Saskatchewan where the days-to-maturity envelope is being pushed. In regions where more flexibility in growing season exists, this may not be an issue. Additionally, if yield is improved with uniform spacing, it presents an opportunity to reduce seed costs for growers. For example, Heath and Hebblethwaite (1987) found that uniform plant spacing reduced seed costs while maintaining yield for pea.

3.2 Acceptable plant spacing uniformity

3.2.1 Theory

Heege and Feldhaus (1997) report that the distance between falling seeds for precision drills follows a normal distribution with a coefficient of variation (C.V.) between 10 and 20%[1]. Heege (1993) reports that the distance between falling seeds for bulk drilling corresponds to an exponential distribution with a C.V. of 100%. It was noted

[1] C.V. is defined as the standard deviation divided by the mean, expressed in percent.

that this distribution does not take into account other factors that affect plant spacing uniformity such as emergence, planter bounce, seed roll upon contact with the soil, and emergence point relative to seed location.

3.2.2 Calculations for determining non-uniformity

Rather than considering the distance between falling seeds, Kachman and Smith (1995) compared various measures for determining plant spacing uniformity. They reported that, since standard deviation is based upon squared deviations from the mean, it is strongly influenced by a few very large spacings, and therefore does not follow a normal distribution. For this reason, the sample mean and standard deviations were deemed to be inappropriate for summarising the plant spacing distributions for precision planters. Measures based on theoretical spacing however appeared to be acceptable.

ISO (1984) provide a procedure for measuring planter seed spacing uniformity in both the laboratory and the field. Seed spacings less than 0.5 times the theoretical spacing are deemed to be multiples (MULT), while seed spacings greater than 1.5 times the theoretical (target or mode) spacing are deemed to be misses (MISS). A quality of feed index (QFI) is calculated by subtracting MISS and MULT from the total number of spaces. All three of these parameters are expressed as a percentage of the total number of spacings.

Smith et al. (1991) introduced a new parameter for comparison of plant spacing uniformity called the "3-cm mode range." This parameter is the percentage of plant spacings that fall within 3 cm of the mode spacing and, unlike the ISO rating, has the advantage of describing the uniformity with one parameter. Furthermore, the range of 3-cm may be varied to suit a desired level of precision.

3.2.3 Laboratory vs. field

In order to offer a fair comparison of planter performance, both laboratory and field evaluations need to be completed. Laboratory evaluations, where seed is dropped onto a moving and sticky surface, offer the advantage of test condition control. Field evaluations are more difficult to conduct, but have the advantage of determining performance under conditions that include planter bounce and vibration. McLean (1974) discusses some of the field factors affecting performance. Jasa and Dickey (1982) report that relative surface roughness, residue, and amount of preplant tillage affected seed spacing uniformity of corn.

Efforts to establish the effectiveness of laboratory results with field results have been minimal. A possible explanation for this is given by Panning (1997) who evaluated sugarbeet planters at the University of Nebraska/Lincoln. It was reported that planters with good spacing uniformity results in the laboratory may have poor spacing uniformity in the field. It was recommended that laboratory tests be conducted first to screen planters with poor spacing uniformity from planters with good spacing uniformity.

3.2.4 Laboratory tests

Halderson (1983) compared four commercial row crop planter units for ability to meter and accurately space five edible bean seed types in the laboratory. None of the planters achieved the arbitrarily chosen QFI of 95%.

PAMI (1984a,b,c) evaluated the seed spacing uniformity of four general purpose planters in the laboratory. Eight different samples of corn, and a sample of large sunflowers were evaluated for QFI according to the ISO 7256/1 standard (ISO 1984). A QFI rating of 95% or better was considered excellent. QFI ratings for corn varied from 87 – 97% for two of the three planters tested. The third planter, with a centralised hopper, had slightly lower QFI ratings. In some cases, QFI values for sunflower seed dropped to 75% which was considered to be poor.

Parish (1999) evaluated a prototype belt seeder for soybean. It was constructed at the recommendation of soybean growers who were seeking an alternative seeder that combined the uniformity of a row-crop planter with the lower cost of a grain drill. The seed spacing uniformity of the prototype seeder was not better than that of the commercial units. None of the commercial units achieved the 90 – 95% QFI range that was considered acceptable.

3.3 In-field measurements of plant spacing uniformity

Kachman and Smith (1995) provide guidelines on the proper sample size for data collection during evaluation of precision planters. They report that the estimated bias at a sample size of 250 was never greater than 0.25%. Therefore, it was concluded that a minimum sample size of 250 be used for data collection. ISO (1984) also recommends a sample size of 250 spacings.

Mclean (1974) used a system of perforated paper strips to automatically determine plant distributions. The number of plant spacings necessary for each evaluation was not provided. Panning et al. (1997) determined seed spacing by removing the soil above the seed immediately after seeding. Toothpicks were placed at the seed locations, and a Plant Spacing Measurement Buggy recorded toothpick locations.

4. Methodology

4.1 Site selection and grower contact

Fifteen growers of dry bean from the Redvers, Rosthern, and Outlook areas were selected. Fifteen growers of kabuli chickpea were selected from the Saskatoon, Rosetown, and Elrose areas. Appendix B provides variety, location, and equipment data for the fields from which data was collected.

4.2 Data collection

At each site, four locations representative of the field were chosen for data collection. Corners and edges of the field where turning was likely to have occurred, were avoided. In addition, areas where the crop was drowned out or growing poorly were avoided.

At each location, a string was stretched across the seed row and data from 75 plant spacings collected. A marker was used to tick off the location of each plant on the string. The strings were then brought back to the laboratory for subsequent data analysis.

5. Discussion

5.1 Limitations of the data

A potential source of error in the data is expected to be the estimate of percent emergence. Personal correspondence with Dr. Steve Shirtliffe (Assistance Professor, Field Crop Agronomy, University of Saskatchewan) revealed that this value could be as low as 60% for dry bean. An estimate of percentage emergence (Appendix B) is included in the analysis based upon the seed rate and seed weight data. However, the accuracy with which the operator calibrated the seeder was unknown.

Another potential limitation of the data, related to the emergence estimate, was the time of collection. By nature, seedlings attacked by disease stop growing shortly after emergence, and consequently may not be noticed during data collection. Therefore, the optimum time for data collection is immediately after emergence. However, due to logistics and field location, this was not always possible. As much as was possible, these plants were included in the data collection process by looking for dead plants that showed signs of a stunted growth pattern.

The spread pattern employed by the opener may also produce a limitation for the data. Most openers were of the knife, or disc-type which made marking plant locations easy. However, one seeder employed the ribbon seeding technique whereby the seed is spread out in a thin layer. This made finding and following the row difficult since they were not as readily discernible. Furthermore, plant distribution in the direction of travel alone, as determined by the string recording method, gives insufficient information about the spacing in the field for the ribbon seeding technique.

5.2 Seed spacing uniformity for dry bean

The ISO (1984) standard, discussed in Section 3.2.2, was chosen for quantifying plant spacing uniformity since it was commonly referenced in the literature. Overall mean QFI was calculated to be 34% (s.d. 8.6%), substantially

lower than the QFI values previously reported for laboratory testing of corn; MULT was 19% (s.d. 5.7%), and MISS was 47% (s.d. 8.6%). Appendix C provides a summary of these parameters for all of the sites.

Although the above values have been provided, they cannot be used as the best indication of plant spacing uniformity since they are based upon the target intra-row spacing determined by the grower. The accuracy with which this value is provided is unknown since monitoring drill calibration was beyond the scope of the project. Additional potential sources of inaccuracy lie with sampling for germination, 1000 seed weight estimates, and sampling for plant population. Although the mode of the intra-row spacing is commonly used to avoid discrepancies in operator adjustment of the seeder, this would have required removing soil to determine seed location immediately after seeding. Once again, this procedure was beyond the scope of the project.

The best indicators of plant spacing uniformity were the histograms created for each field (Appendix D). Histograms do not lend themselves well to data analysis, but in this case data analysis was not necessary. A visual observation of the histograms showed that all fields had non-uniform plant spacing with no apparent spacing trends. An example of a trend that would indicate the seeder was seeding in a uniform manner would be multiple peaks. For instance, if a target spacing is 40 mm, the largest distribution would be around 40 mm. If, as one would expect, misses occurred there would be a subsequent smaller distribution around 80 mm. In all of the histograms, no clear distribution can be seen indicating that the distribution of plant spacings was non-uniform. Kachman and Smith (1995) provide an example of the relative uniformity of histogram data for two planters. Figure A1 (Appendix A), taken at Site 12, shows typical non-uniformity in plant spacing.

It is noted that the data from Site 10 was not used due to suspected seed damage from the metering mechanism. It is also noted that data were not collected from Site 15. Although this site was seeded with a corn planter, it was considered atypical of the uniformity in spacing expected from a precision planter.

5.3 Seed spacing uniformity for chickpea

The ISO (1984) standard, discussed in Section 3.2.2, was chosen for quantifying plant spacing uniformity since it was commonly referenced in the literature. Overall mean QFI was 37% (s.d. 4.9%), substantially lower than the QFI values previously reported for laboratory testing of corn; MULT was 30% (s.d. 6.1%), and MISS was 33% (s.d. 8.2%). Appendix C provides a summary of these parameters for all of the sites.

Although the above values are provided, they cannot be used as the best indication of plant spacing uniformity since they are based upon the target intra-row spacing determined by the grower. The accuracy with which this value is provided is unknown since monitoring drill calibration was beyond the scope of the project. Additional potential sources of inaccuracy lie with sampling for germination, 1000 seed weight estimates, and sampling for plant population. Although the mode of the intra-row spacing is commonly used to avoid discrepancies in operator adjustment of the seeder, this would have required removing soil to determine seed location immediately after seeding. Once again, this procedure was beyond the scope of the project.

The best indicators of plant spacing uniformity were the histograms created for each field (Appendix E). Histograms do not lend themselves well to data analysis, but in this case data analysis was not necessary. A visual observation of the histograms showed that all fields had non-uniform plant spacing with no apparent spacing trends. An example of a trend that would indicate the seeder was seeding in a uniform manner would be multiple peaks. For example, if a target spacing is 40 mm, the largest distribution would be around 40 mm. If, as one would expect, misses occurred there would be a subsequent smaller distribution around 80 mm. In all of the histograms, no clear distribution can be seen indicating that the distribution of plant spacings was non-uniform. Kachman and Smith (1995) show relative uniformity of histogram data for two planters. Figure A2 (Appendix A) taken at Site 15, shows typical non-uniformity in plant spacing.

5.4 Need for add-on singulator

The data show that the intra-row plant spacing of the dry bean and kabuli chickpea fields sampled was non-uniform. This indicates the need for an add-on singulator, but consideration must be given to other factors. The literature has revealed that precision planting of some crops does not always result in improved yield. Although preliminary

experiments have revealed an increase in yield for two varieties of dry bean, similar work has not been completed, or discovered in the literature, for chickpea.

Intuitively, other factors point to the need for an improved uniformity of plant spacing and include:

- a potentially more uniform maturity at harvest with subsequent improvement in seed quality. Seed quality is an important consideration for chickpea and bean varieties sold into the salad market. Uniform maturity may also be more difficult to obtain in Saskatchewan with its inherently shorter growing season.
- a reduced disease pressure by preventing plants from being spaced too close together.
- a reduced weed pressure when the large spacings between plants are reduced.
- a reduced seed cost if yield can be maintained while using less seed.

Another reason for pursuing development of a low-cost add-on singulator is that the requirement for "low-cost" may be attainable. Since the inter-row spacing of conventional seeders is narrower than that for planters, the intra-row spacing is therefore not as close, and the requirement for precise spacing within the seed row should not be as great. With less importance on this design constraint, it may be possible to develop an add-on singulator that would sell for a low-cost.

5.5 Other

The data also show an interesting trend for bean fields seeded to Camino. Seeding rates seem to be low resulting in target plant populations that are also low. This, coupled with low emergence rates, may result in significantly lower plant populations and potentially reduced yields. Additionally, the data for this project was sampled from locations with good plant populations. Therefore, average plant populations for each site will be lower where bare or drowned out spots are present. Some extension work may be necessary to ensure that growers of the larger-sized seed varieties achieve the recommended plant populations.

6. Conclusions

1) Plant spacing uniformity from representative bean and kabuli chickpea fields, seeded with conventional bulk seed metering equipment in Saskatchewan, was found to be non-uniform. The measure of non-uniformity was based upon a subjective, but skilled observation of histogram data for each field, rather than an objective calculation of degree of non-uniformity.
2) A low-cost, add-on singulator is needed to improve plant spacing uniformity of dry bean and kabuli chickpea. Development of the singulator should proceed after considering the recommendations of Section 7.
3) The literature revealed a trend to narrower rows, with an accompanying equidistant plant spacing, for the major row crops of the North Central USA. Saskatchewan growers have the opportunity to capitalise on this trend by adapting their equipment for these crops. Without the need to purchase costly row crop equipment, a competitive advantage is possible.
4) Extension work may be needed to ensure that growers of the larger sized bean seed varieties achieve recommended plant populations.

7. Recommendations

1) Arrange, in order of priority, the other factors of Section 5.4 that point to the need for a more uniform plant spacing. This could be completed by industry stakeholders and scientists.
2) Completion of a literature review, specific to the items of Section 5.4, with the intent of determining the need for additional scientific research work on the same.
3) Completion of equidistant plant spacing trials, specific to varieties of dry bean and chickpea expected to be grown in Saskatchewan. The trials could be designed to confirm a yield increase effect, or the importance of the items of Section 5.4.
4) Recognising that the research required in the previous recommendation may be costly, an alternative would be to use the funding for actual development of the singulator. A manufacturer of the device would then have the opportunity to market it for crops that benefit from uniform plant spacing. Additionally, if development of the singulator is successful, it could be used for all large seed crops at little cost to the industry (for research dollars), and to the grower.

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9. Other

9.1 Project activities, achievements, papers, presentations, etc.

- Data on plant population and preliminary uniformity results were presented at two grower extension meetings: Rosthern – 2000/12/11, Redvers – 2000/12/18.
- A response to the call for papers, Soils & Crops Workshop (2001), has been submitted.
- A summary of the final report will be submitted for publication in the Saskatchewan Pulse Growers Newsletter.

9.2 Indications for further development

Indications for further development are provided in the recommendations of Section 7.

9.3 Information of benefit to producers, processors, or government

- Producers will be particularly interested in this information, as it will offer them an opportunity to compare the plant spacing uniformity of their crop with a representative sample of Saskatchewan kabuli chickpea and dry bean growers.
- It will also draw their attention to the effect of plant spacing uniformity on yield, quality, seed costs, and other factors.
- In the case of dry bean, the information from the report shows the importance of aiming for a correct target plant population.

9.4 Deviations from work plan

- Data were collected from nine additional grower sites than originally anticipated. This was deemed appropriate since the fields were close. In addition, one bean field, sown with a planter, was visited for comparison purposes.
- Data collection was completed later than optimum as discussed in the report.
- No significant deviations from the work plan were necessary.

APPENDIX A: PHOTOS SHOWING TYPICAL NON-UNIFORM SPACING

Figure A1: Non-uniformity of bean plant spacings (Field B12)

Figure A2: Non-uniformity of chickpea plant spacings (Field C15)

APPENDIX B: SITE AND EQUIPMENT DATA

Table I: Dry bean variety, location, seeder-type, and agronomic data.

	Dry bean variety/cultivar	Location	Seeder-type	Target Population (plants/m^2)	Actual Population (plants/m^2)	Emergence* (%)
1	Pinto/Camino	Outlook	Air seeder	24	18	79
2	Black/Nighthawk	Oxbow	Hoe drill	45	25	69
3	Black/Nighthawk	Glen Ewen	Hoe drill	39	23	72
4	Black/Expresso	Carnduff	Air seeder	37	17	57
5	Pinto/Camino	Redvers	Air seeder	23	13	60
6	Navy/Envoy	Redvers	Air seeder	34	15	48
7	Pinto/Camino	Redvers	Air seeder	24	15	64
8	Pinto/Camino	Redvers	Air seeder	26	14	59
9	Pinto/Camino	Redvers	Air seeder	24	10	42
10	Pinto/Camino	Data not used**	Hoe drill	N/A	N/A	N/A
11	Pinto/Camino	Redvers	Hoe drill	21	18	89
12	Black/Nighthawk	Redvers	Air seeder	37	14	39
13	Black/Expresso	Rosthern	Air seeder	42	21	53
14	Black/Expresso	Rosthern	Air seeder	42	28	72
15	Black	Hepburn	Planter**8	N/A	N/A	N/A

*Target population values are not adjusted for germination, while emergence values are.
** Suspected damage from metering mechanism.
*** No data collected, slides only.

Table II: Kabuli chickpea variety, location, seeder-type, and agronomic data.

	Cultivar	Location	Seeder-type	Target Population (plants/m^2)	Actual Population (plants/m^2)	Emergence* (%)
1	Chico	Smuts	Hoe drill	86	60	70
2	B90	Outlook	Air seeder	52	35	73
3	Dwelley	Elrose	Air seeder	29	17	59
4	Sanford	Kyle	Air seeder	42	36	98
5	Sanford	Elrose	Air seeder	28	30	117**
6	Sanford	Kyle	Air seeder	48	34	75
7	Sanford	Sanctuary	Air seeder	54	35	66
8	Sanford	Harris	Air seeder	33	25	76
9	Sanford	Zealandia	Air seeder	31	27	91
10	Sanford	Rosetown	Air seeder	33	26	79
11	Sanford	Glamis	Air seeder	33	27	82
12	Sanford	Eston	Air seeder	32	26	87
13	Sanford	Eston	Air seeder	30	32	118
14	Sanford	Eston	Air seeder	29	27	103
15	Dwelley	Isham	Air Seeder	32	24	77

* Target population values are not adjusted for germination, while emergence values are.
**Emergence values greater than 100% demonstrate the inaccuracy in setting seed rate, sampling for germination estimate, estimating 1000 seed weight, and/or sampling for plant population.

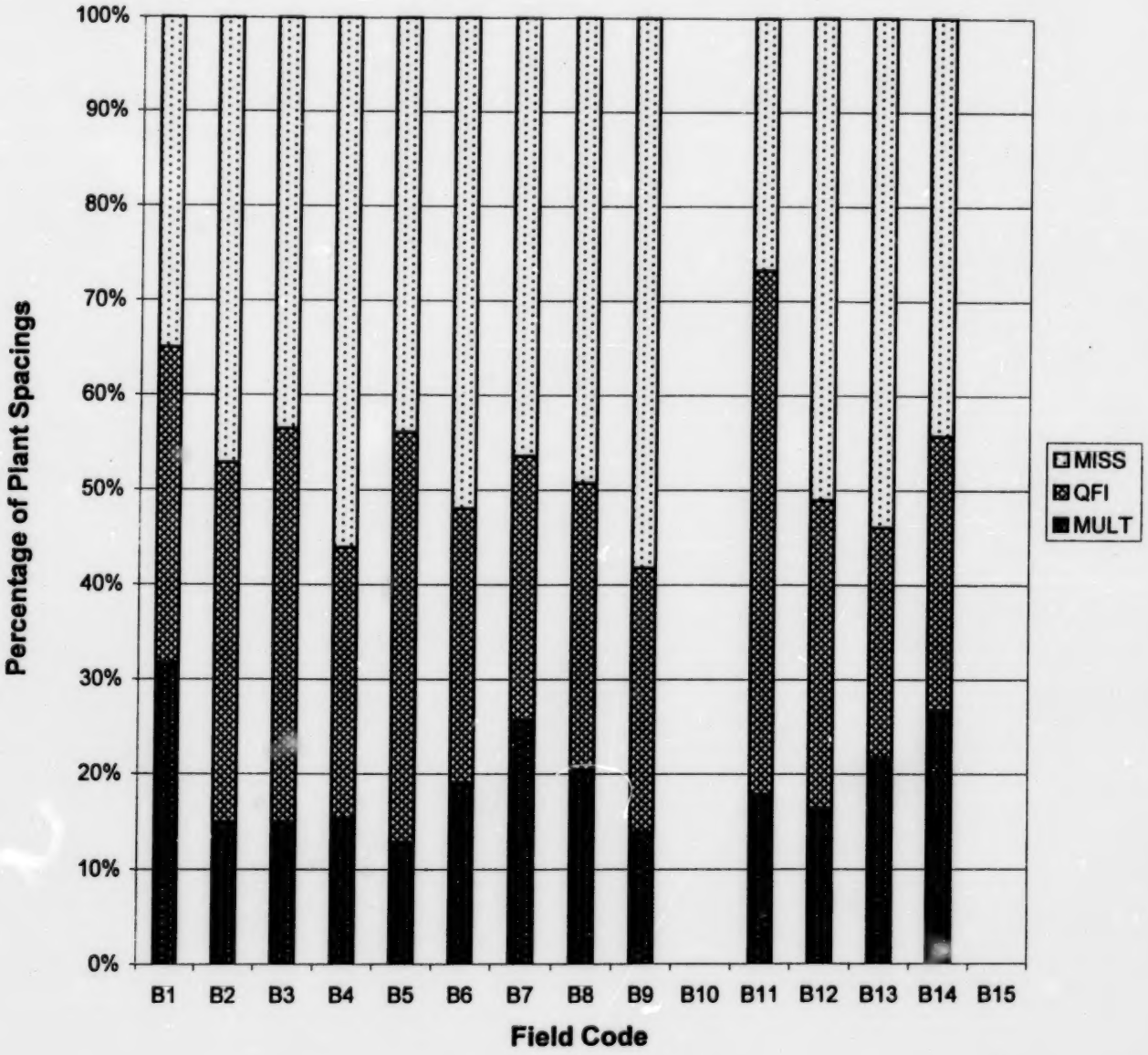


Figure C1: Bean Plant Spacing Summary

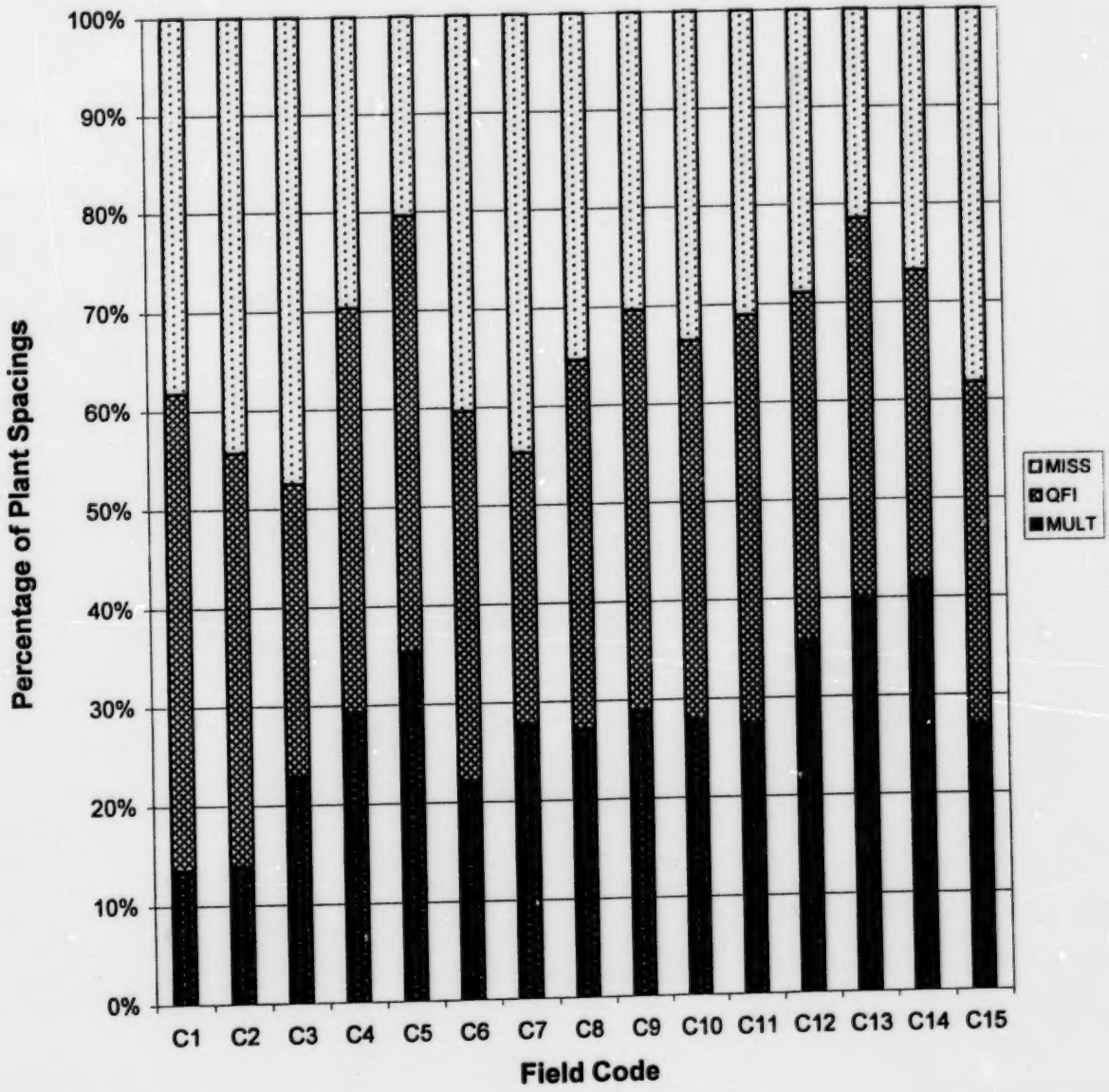
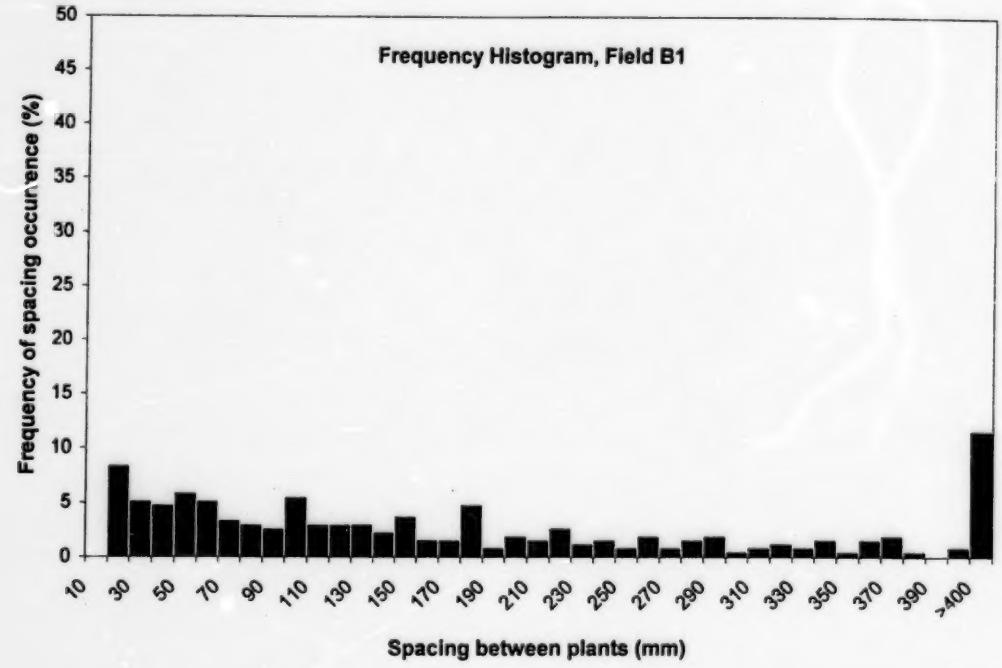
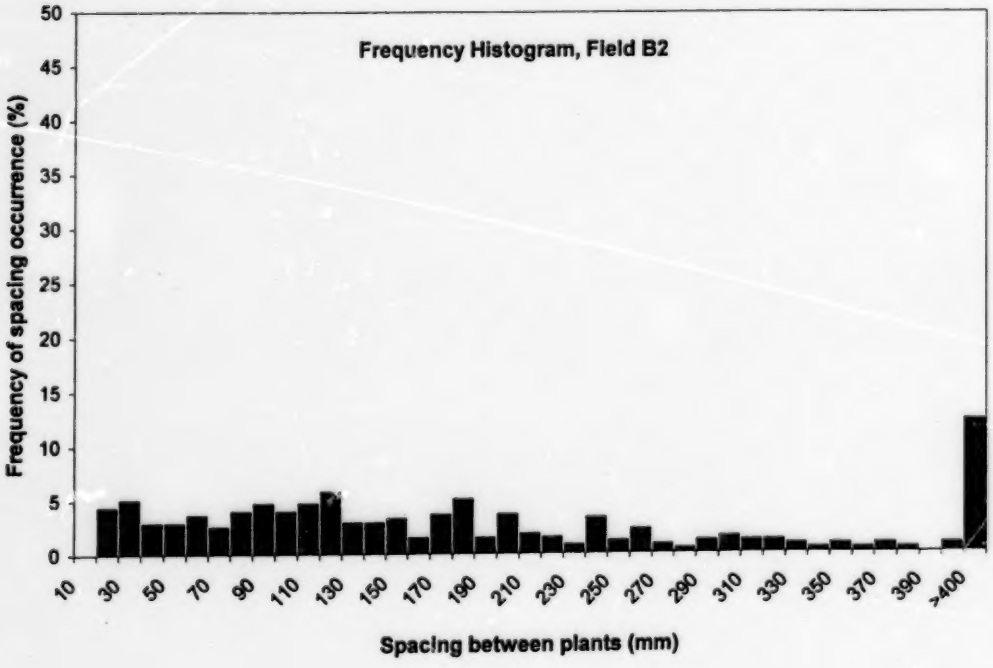


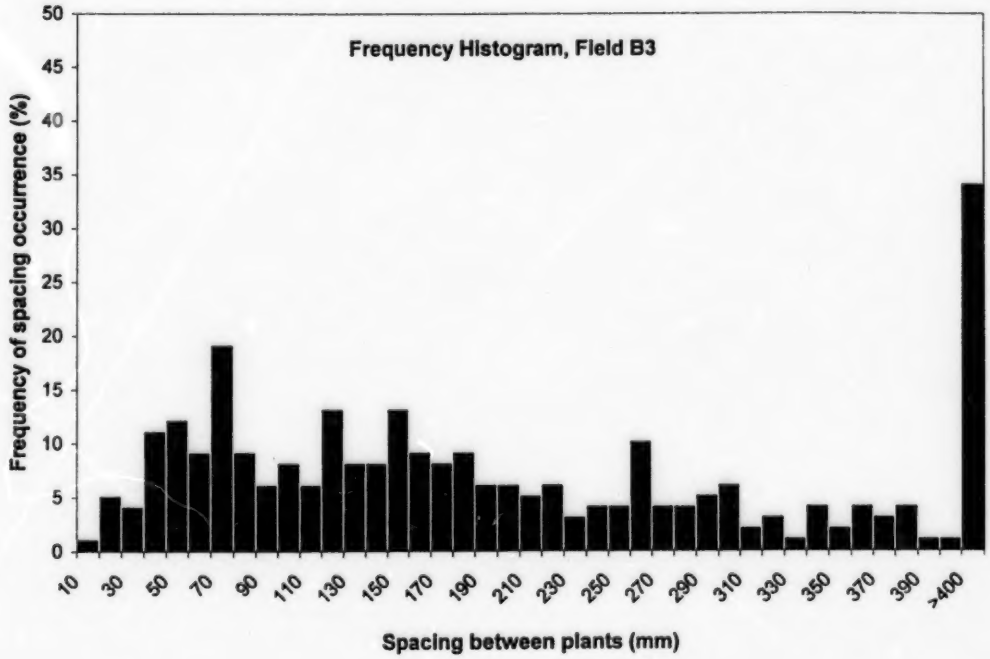
Figure C2: Chickpea Plant Spacing Summary

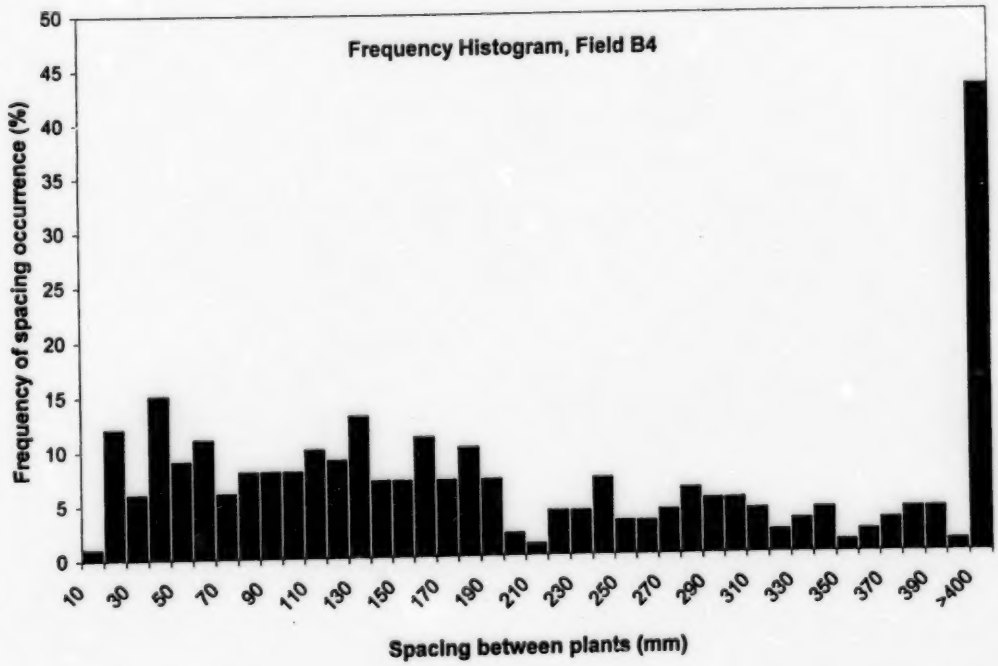
APPENDIX D: FREQUENCY HISTOGRAMS: DRY BEAN[2]





[2] Histograms were not adjusted for emergence. Emergence was assumed to be evenly distributed among MISS, MULT, and QFI.


Frequency Histogram, Field B3
Frequency of spacing occurrence (%)
0
5
10
15
20
25
30
35
40
45
50
10
30
50
70
90
110
130
150
170
190
210
230
250
270
290
310
330
350
370
390
>400
Spacing between plants (mm)


Frequency Histogram, Field B4
Frequency of spacing occurrence (%)
0
5
10
15
20
25
30
35
40
45
50
10
30
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90
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130
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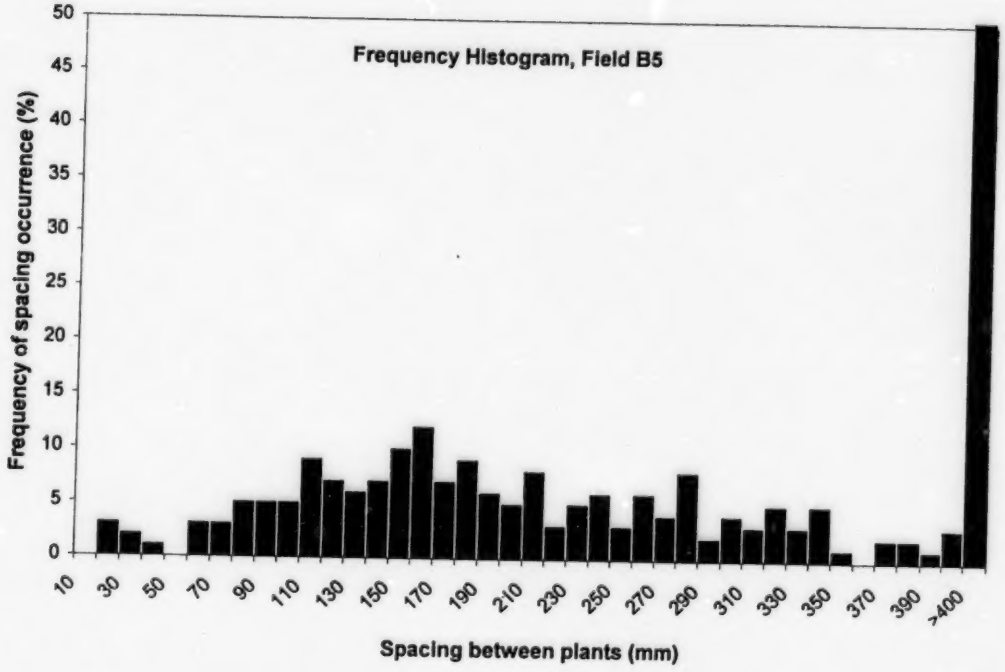
170
190
210
230
250
270
290
310
330
350
370
390
>400
Spacing between plants (mm)


Frequency Histogram, Field B5
Frequency of spacing occurrence (%)
0
5
10
15
20
25
30
35
40
45
50
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70
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110
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170
190
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230
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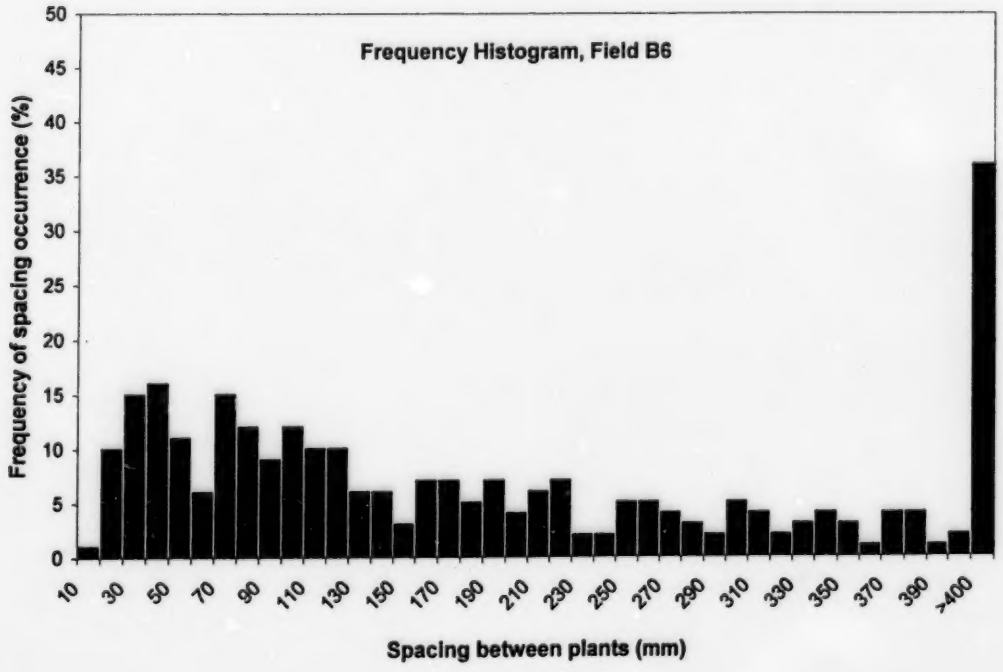
270
290
310
330
350
370
390
>400
Spacing between plants (mm)


Frequency Histogram, Field B6
Frequency of spacing occurrence (%)
0
5
10
15
20
25
30
35
40
45
50
10
30
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70
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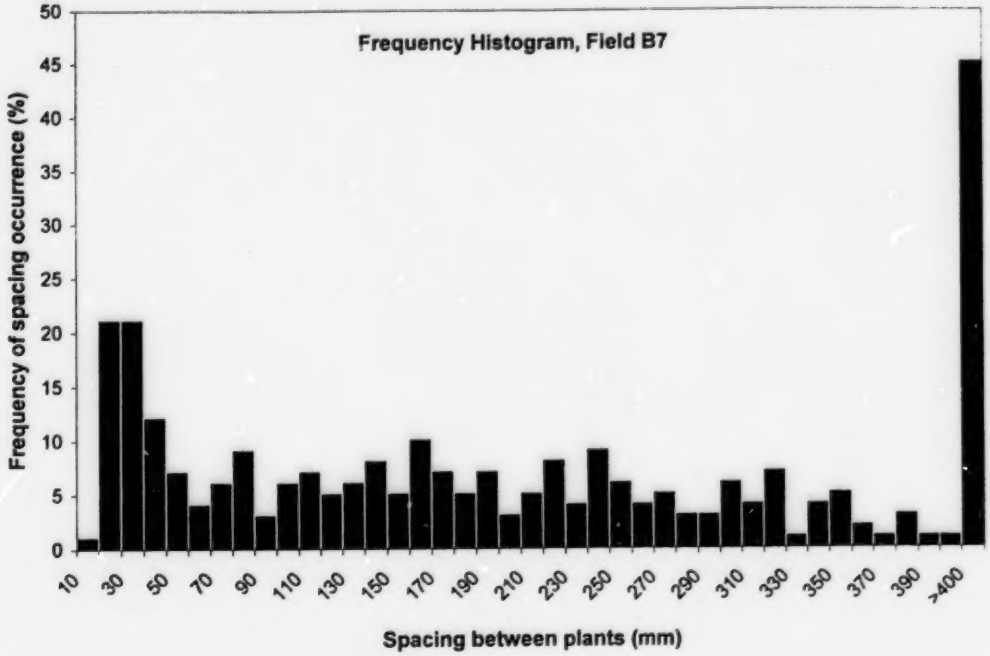
350
370
390
>400
Spacing between plants (mm)


Frequency Histogram, Field B7
Frequency of spacing occurrence (%)
0
5
10
15
20
25
30
35
40
45
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10
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130
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170
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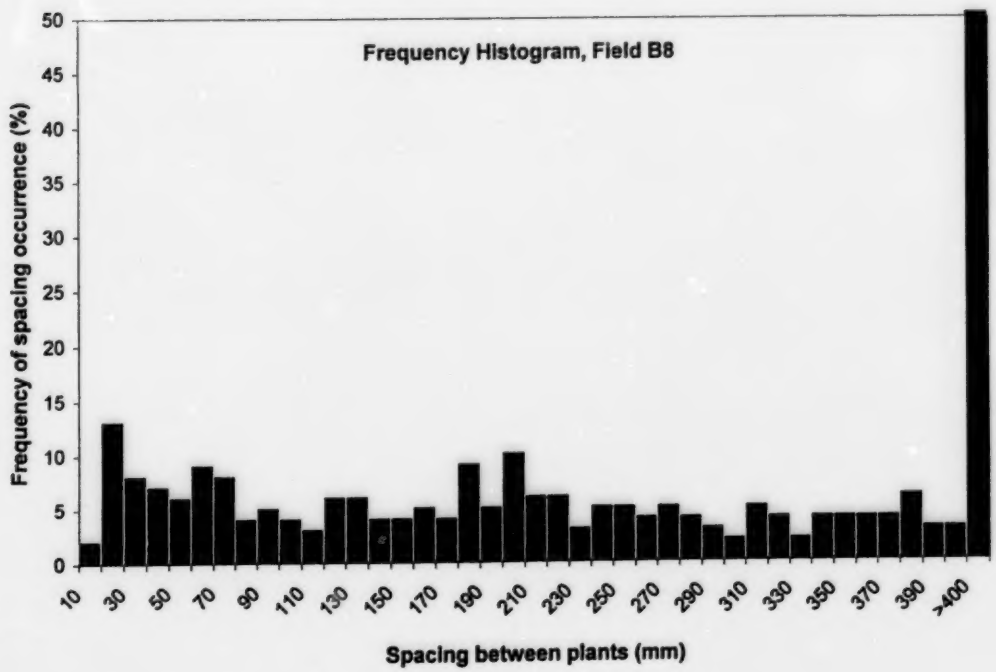
350
370
390
>400
Spacing between plants (mm)


Frequency Histogram, Field B8
Frequency of spacing occurrence (%)
0
5
10
15
20
25
30
35
40
45
50
10
30
50
70
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110
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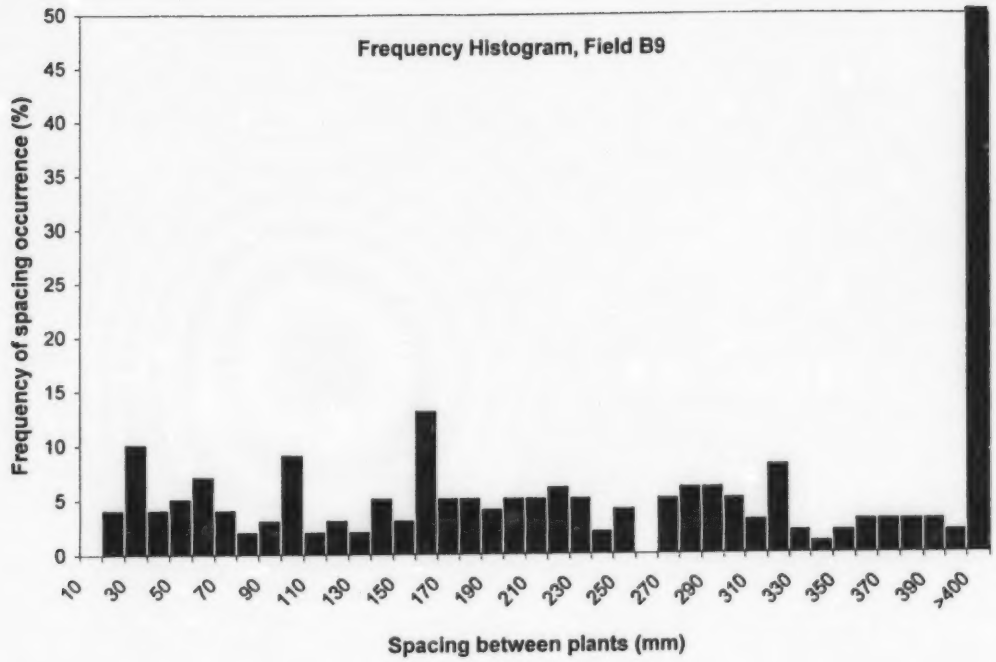
170
190
210
230
250
270
290
310
330
350
370
390
>400
Spacing between plants (mm)


Frequency Histogram, Field B9
Frequency of spacing occurrence (%)
0
5
10
15
20
25
30
35
40
45
50
10
30
50
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90
110
130
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170
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230
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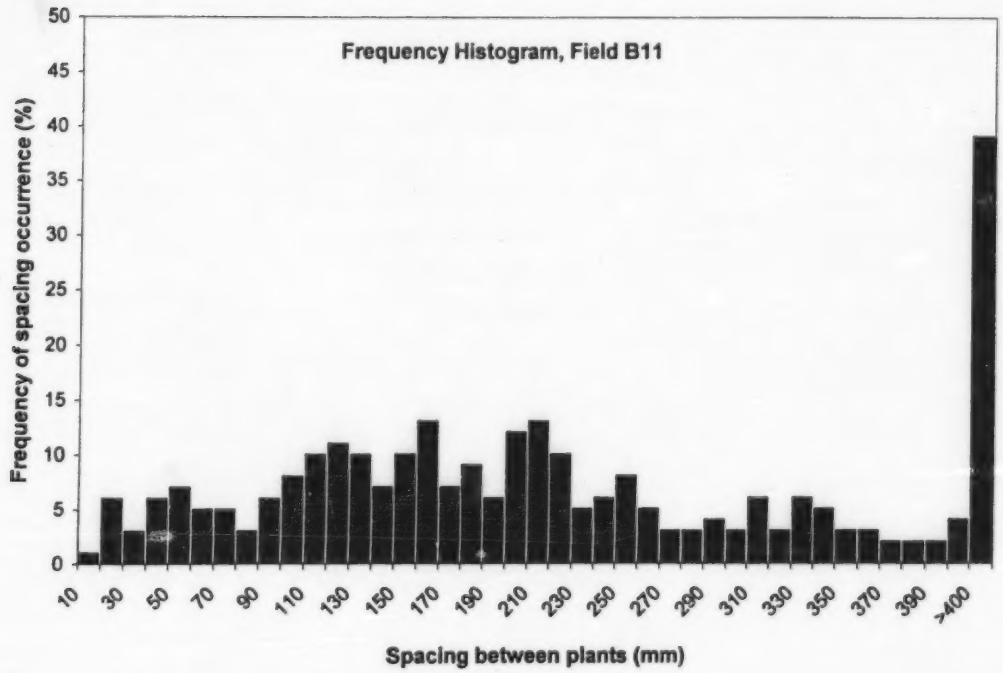
330
350
370
390
>400
Spacing between plants (mm)


Frequency Histogram, Field B11
Frequency of spacing occurrence (%)
0
5
10
15
20
25
30
35
40
45
50
10
30
50
70
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110
130
150
170
190
210
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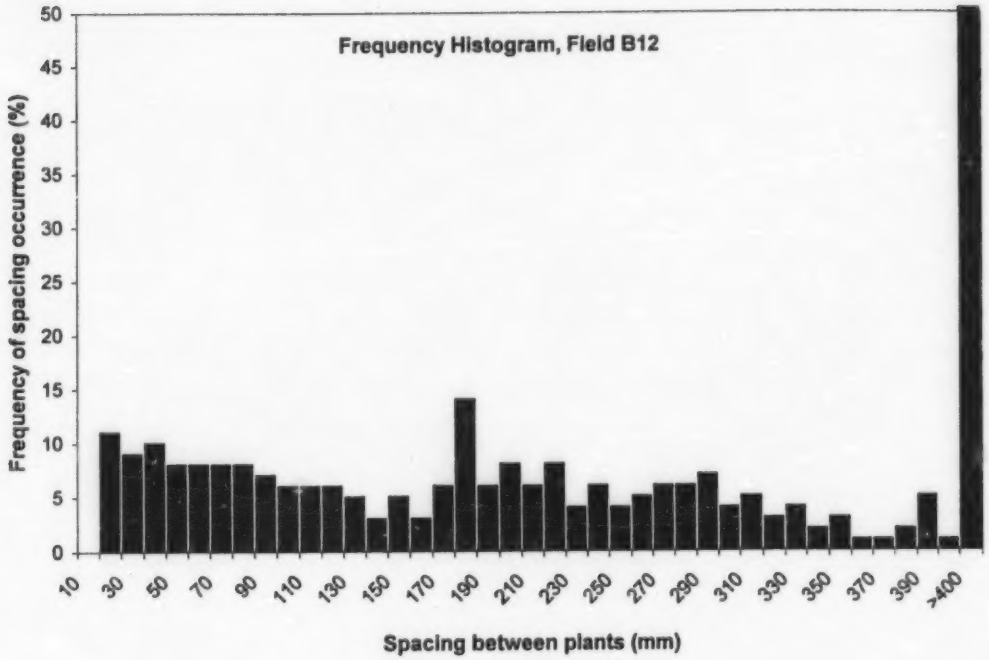
330
350
370
390
>400
Spacing between plants (mm)


Frequency Histogram, Field B12
Frequency of spacing occurrence (%)
0
5
10
15
20
25
30
35
40
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70
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290
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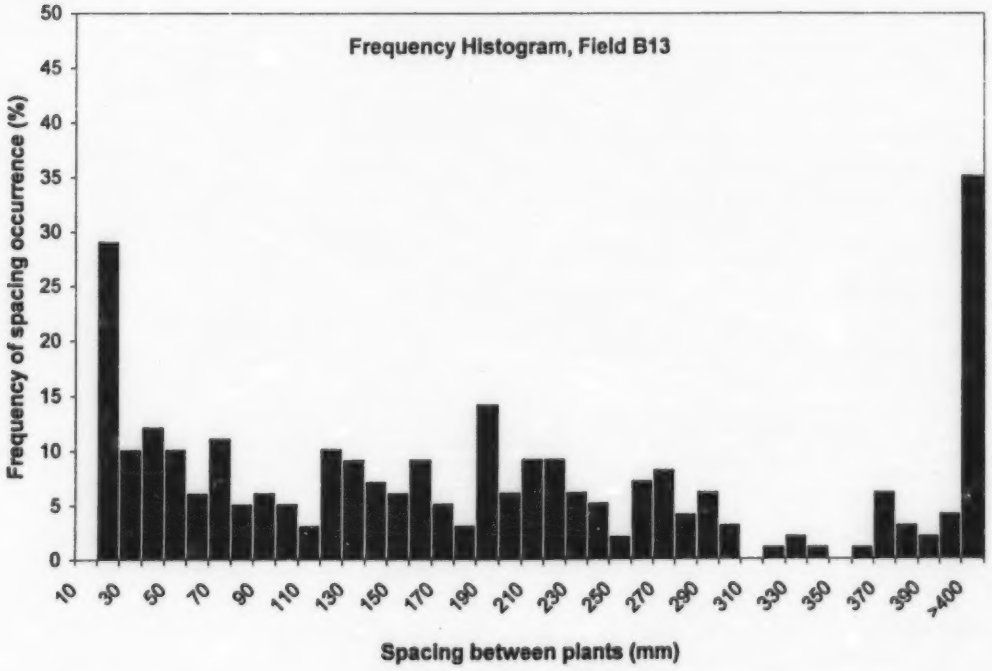
330
350
370
390
>400
Spacing between plants (mm)


Frequency Histogram, Field B13
Frequency of spacing occurrence (%)
0
5
10
15
20
25
30
35
40
45
50
10
30
50
70
90
110
130
150
170
190
210
230
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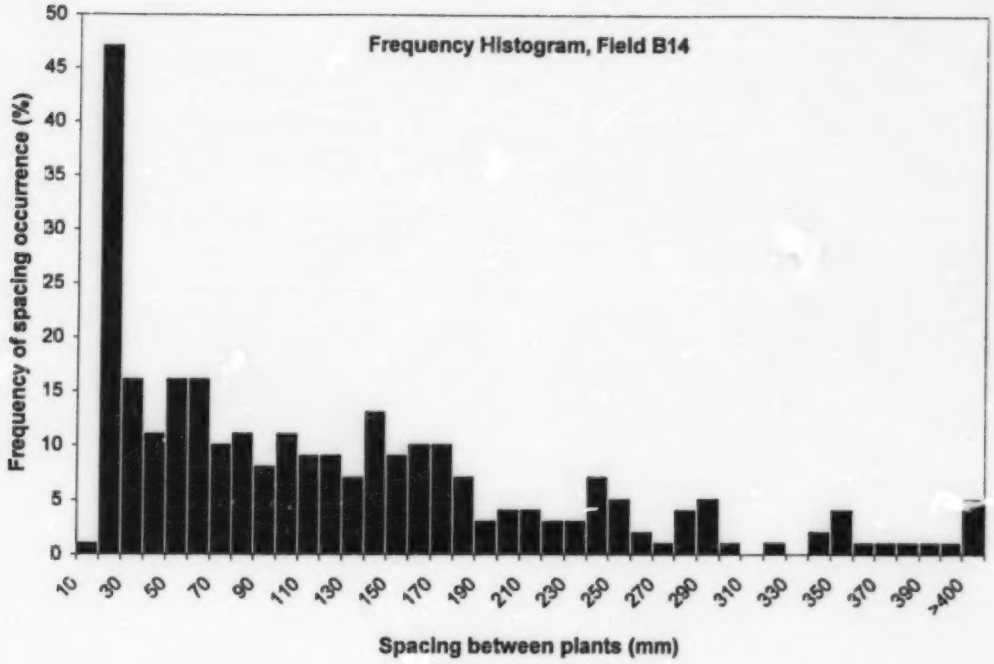
290
310
330
350
370
390
>400
Spacing between plants (mm)


Frequency Histogram, Field B14
Frequency of spacing occurrence (%)
50
45
40
35
30
25
20
15
10
5
0
10
30
50
70
90
110
130
150
170
190
210
230
250
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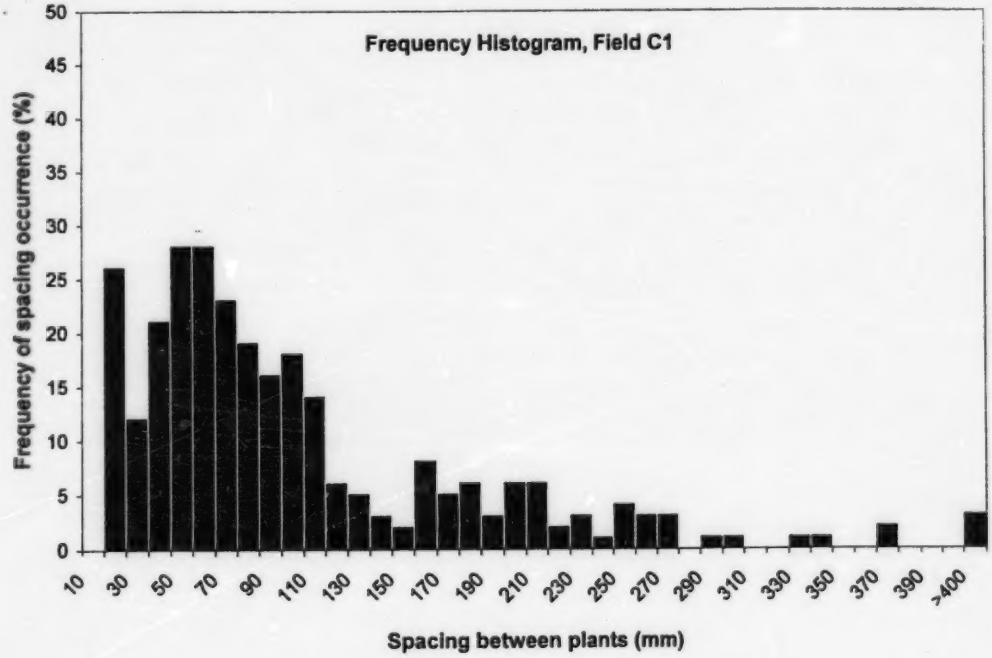
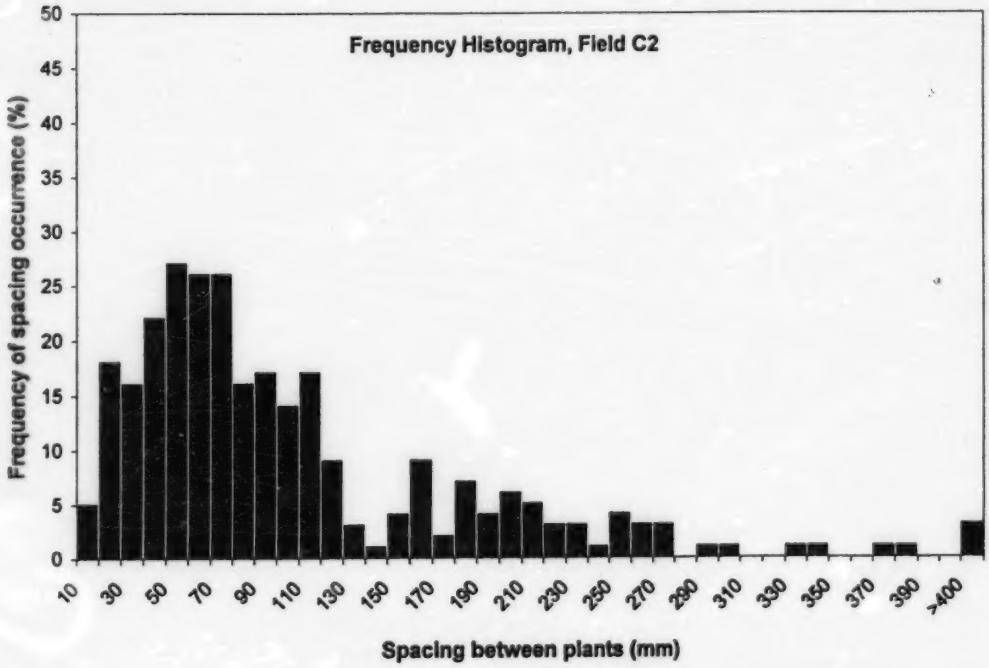
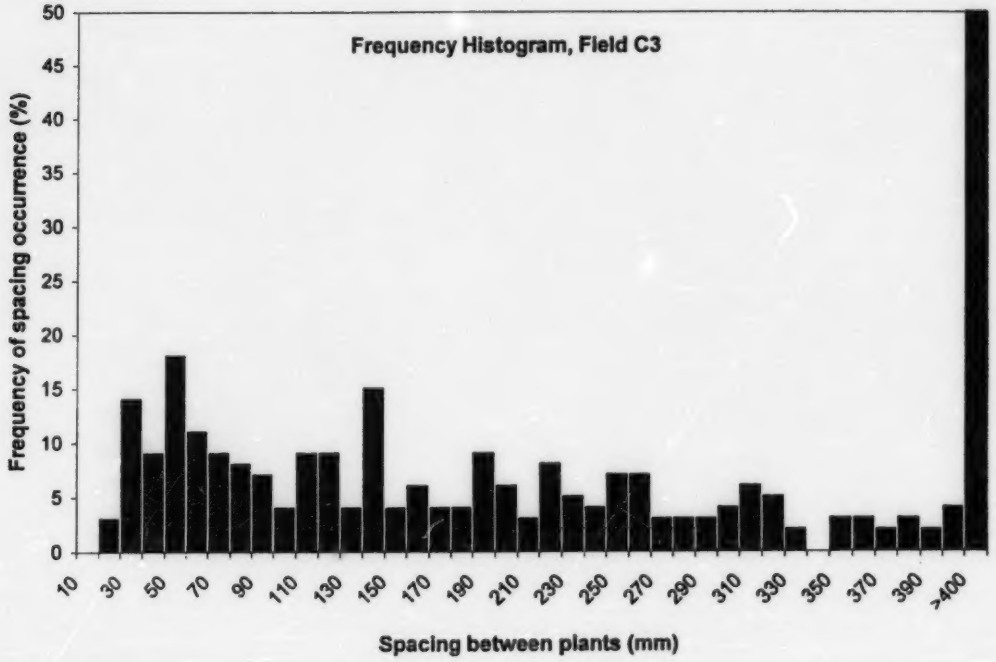
290
310
330
350
370
390
>400
Spacing between plants (mm)

APPENDIX E: FREQUENCY HISTOGRAMS: CHICKPEA[3]





[3] Histograms were not adjusted for emergence. Emergence was assumed to be evenly distributed among MISS, MULT, and QFI.


Frequency Histogram, Field C3
Frequency of spacing occurrence (%)
0
5
10
15
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25
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50
10
30
50
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90
110
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170
190
210
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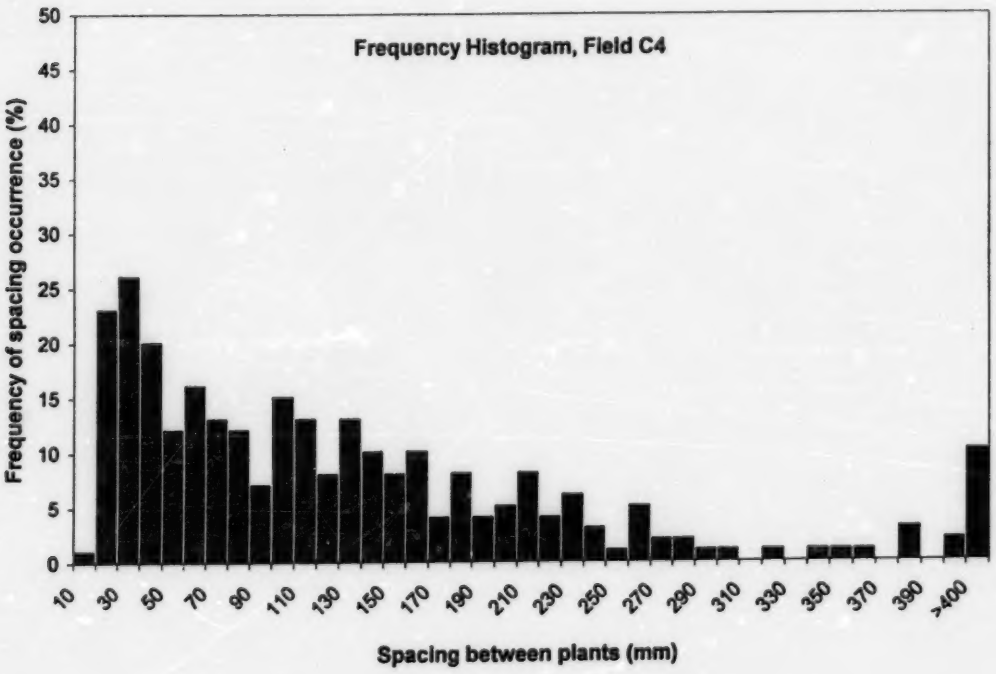
270
290
310
330
350
370
390
>400
Spacing between plants (mm)


Frequency Histogram, Field C4
Frequency of spacing occurrence (%)
0
5
10
15
20
25
30
35
40
45
50
10
30
50
70
90
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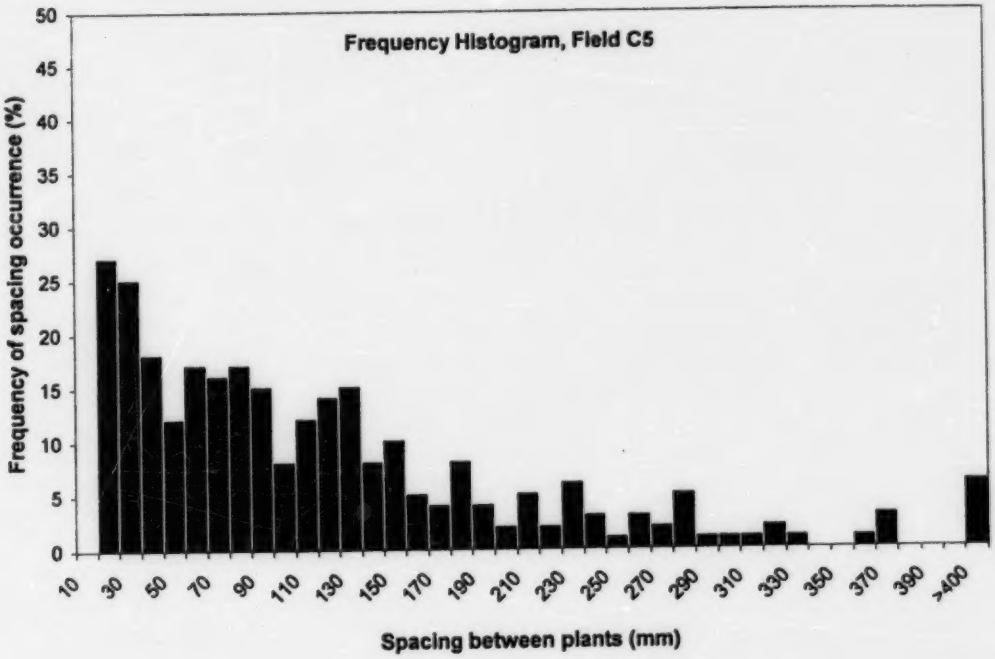
170
190
210
230
250
270
290
310
330
350
370
390
>400
Spacing between plants (mm)


Frequency Histogram, Field C5
Frequency of spacing occurrence (%)
0
5
10
15
20
25
30
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190
210
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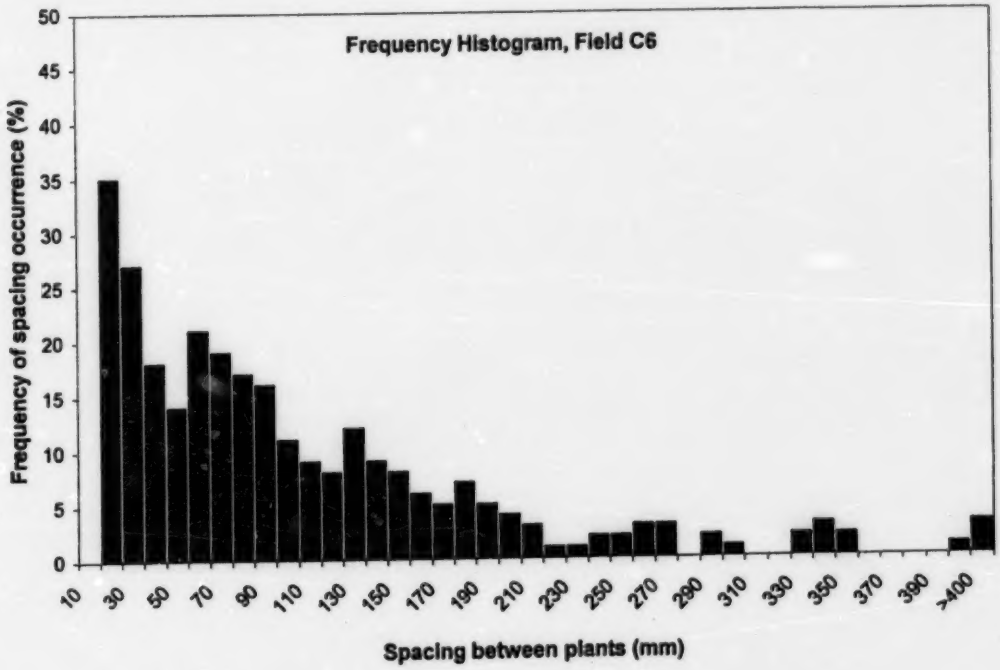
290
310
330
350
370
390
>400
Spacing between plants (mm)


Frequency Histogram, Field C6
Frequency of spacing occurrence (%)
0
5
10
15
20
25
30
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45
50
10
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50
70
90
110
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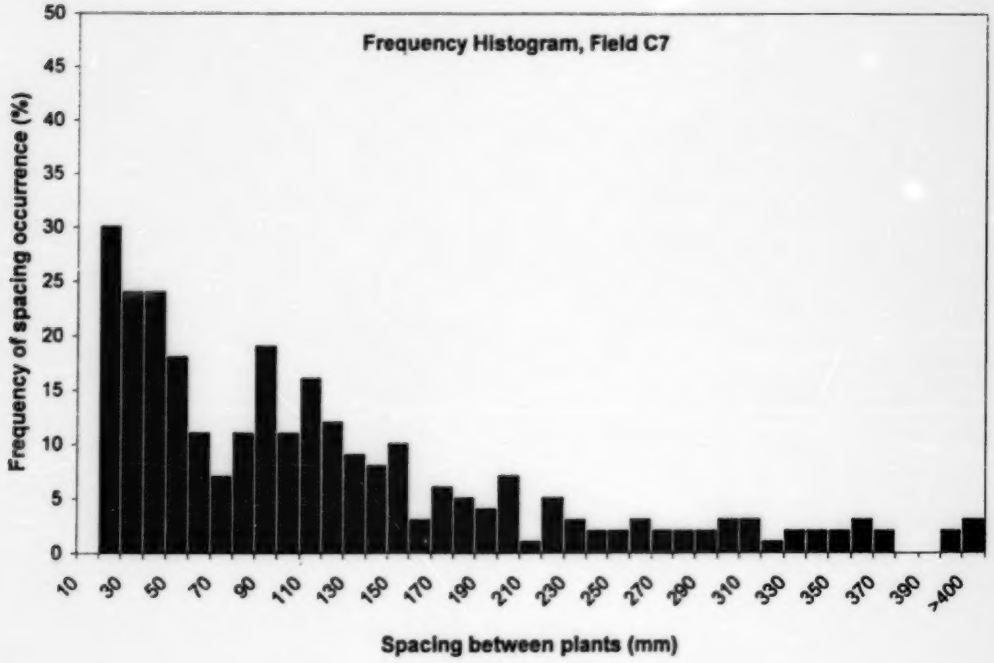
170
190
210
230
250
270
290
310
330
350
370
390
>400
Spacing between plants (mm)


Frequency Histogram, Field C7
Frequency of spacing occurrence (%)
0
5
10
15
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25
30
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40
45
50
10
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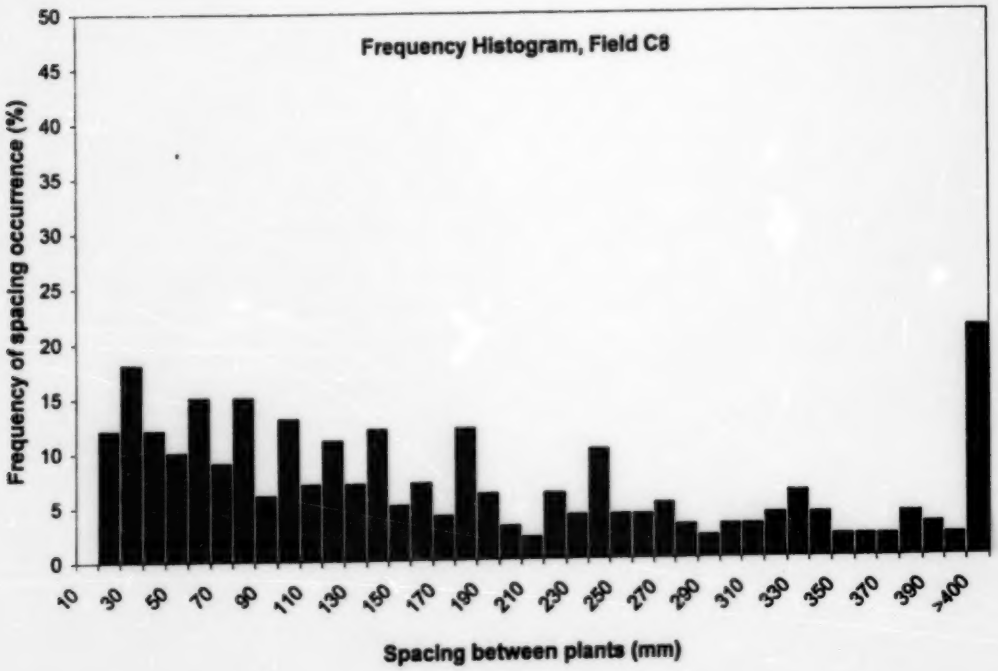
70
90
110
130
150
170
190
210
230
250
270
290
310
330
350
370
390
>400
Spacing between plants (mm)


Frequency Histogram, Field C8
Frequency of spacing occurrence (%)
0
5
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45
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50
70
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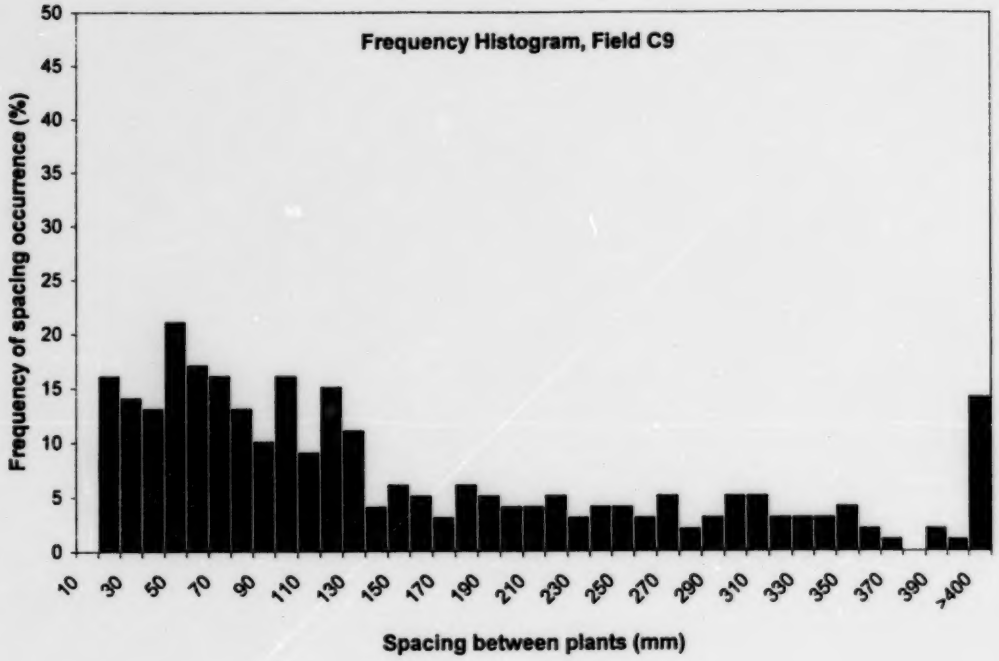
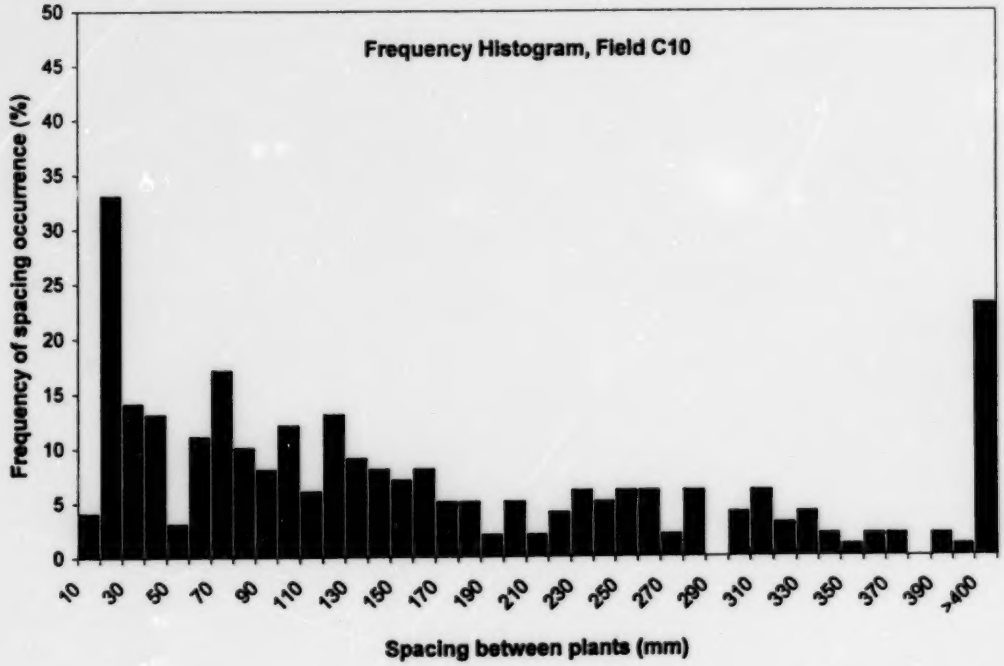
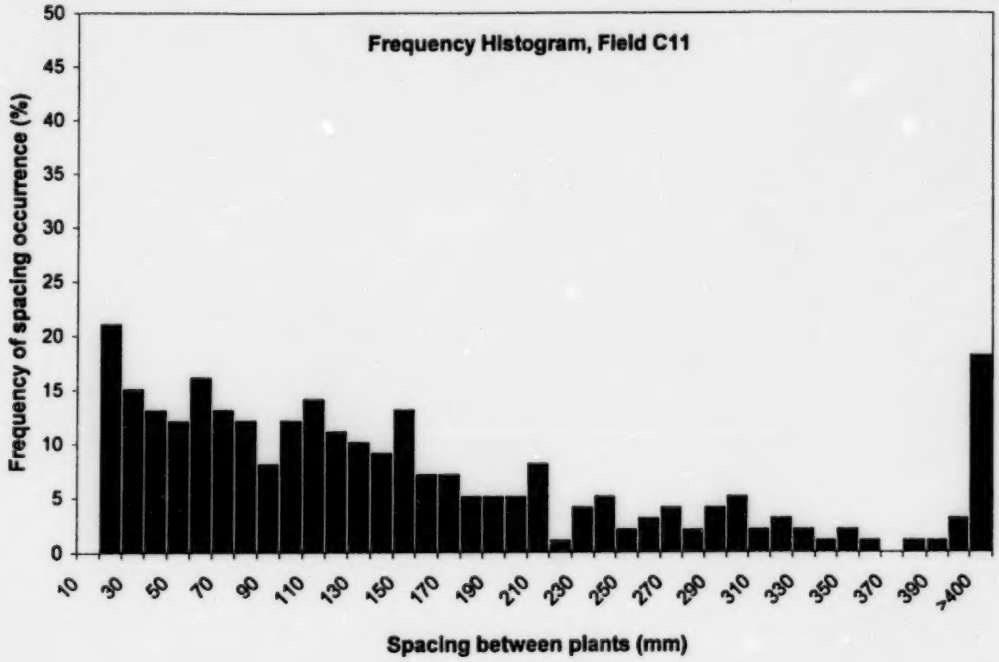
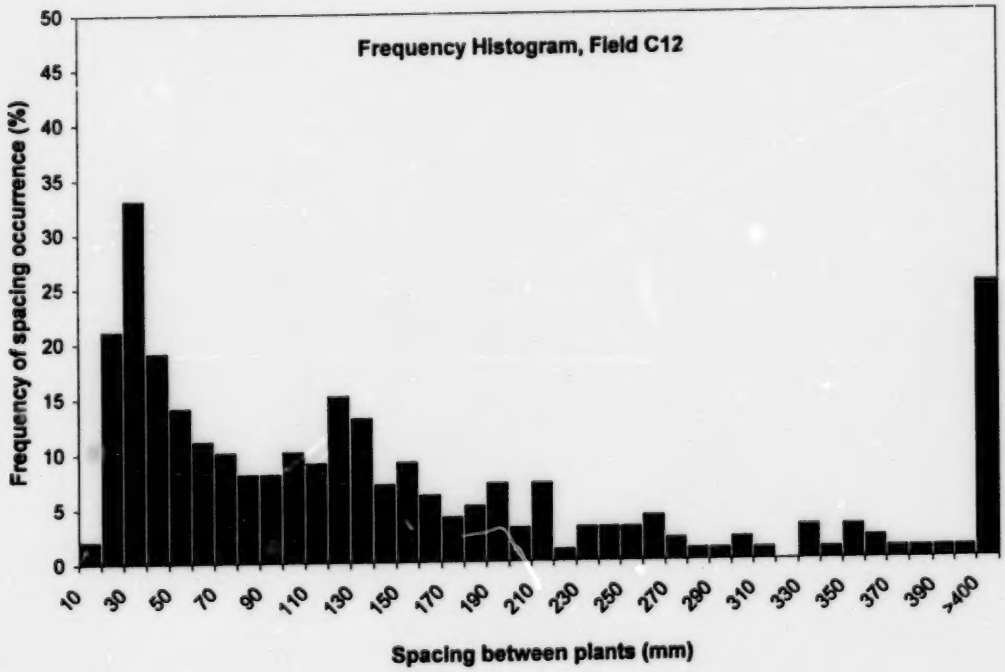
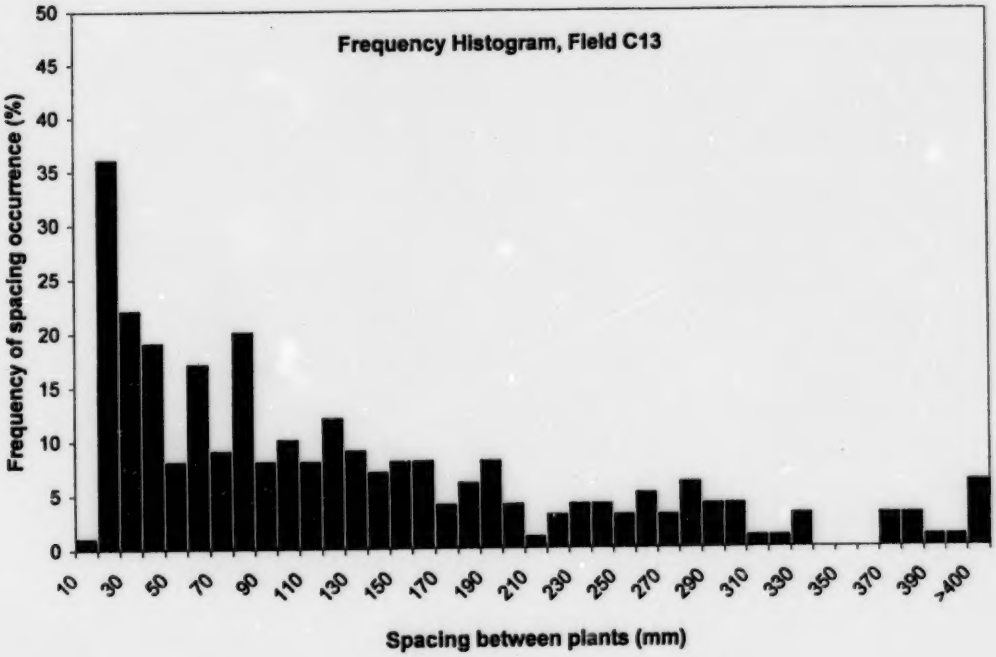
130
150
170
190
210
230
250
270
290
310
330
350
370
390
>400
Spacing between plants (mm)

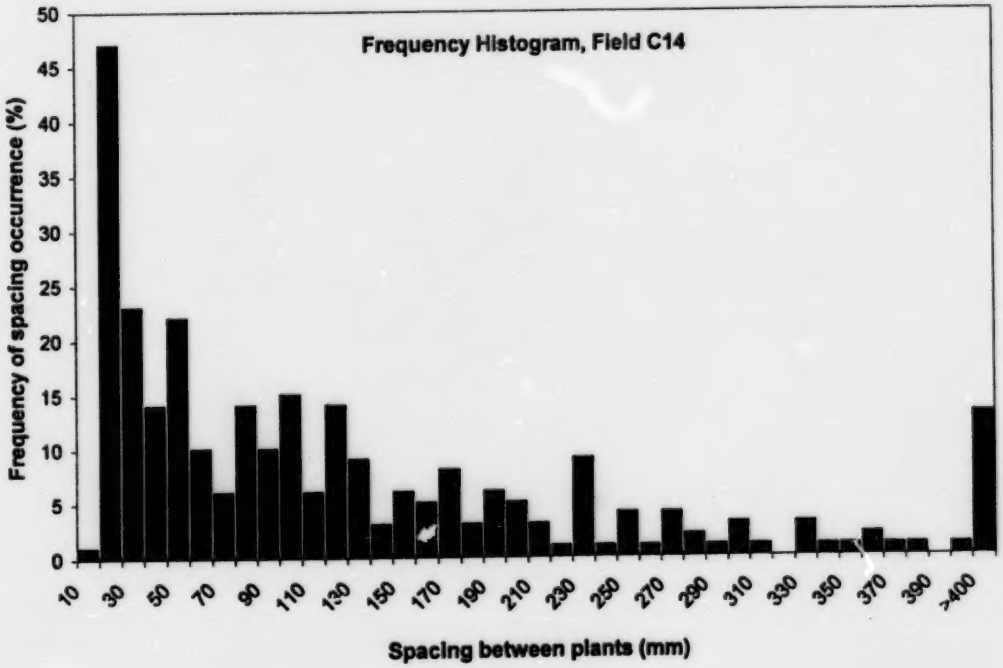

Frequency Histogram, Field C9
Frequency of spacing occurrence (%)
0
5
10
15
20
25
30
35
40
45
50
10
30
50
70
90
110
130
150
170
190
210
230
250
270
290
310
330
350
370
390
>400
Spacing between plants (mm)

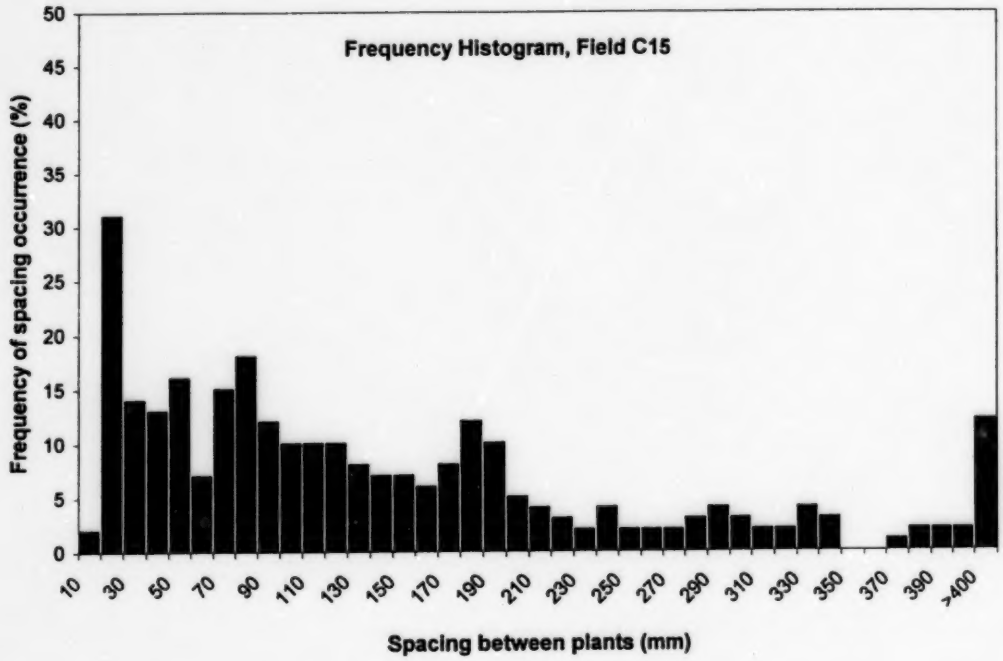

Frequency Histogram, Field C10
Frequency of spacing occurrence (%)
0
5
10
15
20
25
30
35
40
45
50
10
30
50
70
90
110
130
150
170
190
210
230
250
270
290
310
330
350
370
390
>400
Spacing between plants (mm)


Frequency Histogram, Field C11
Frequency of spacing occurrence (%)
0
5
10
15
20
25
30
35
40
45
50
10
30
50
70
90
110
130
150
170
190
210
230
250
270
290
310
330
350
370
390
>400
Spacing between plants (mm)


Frequency Histogram, Field C12
Frequency of spacing occurrence (%)
0
5
10
15
20
25
30
35
40
45
50
10
30
50
70
90
110
130
150
170
190
210
230
250
270
290
310
330
350
370
390
>400
Spacing between plants (mm)


Frequency Histogram, Field C13
Frequency of spacing occurrence (%)
0
5
10
15
20
25
30
35
40
45
50
10
30
50
70
90
110
130
150
170
190
210
230
250
270
290
310
330
350
370
390
>400
Spacing between plants (mm)


Frequency Histogram, Field C14
Frequency of spacing occurrence (%)
0
5
10
15
20
25
30
35
40
45
50
10
30
50
70
90
110
130
150
170
190
210
230
250
270
290
310
330
350
370
390
>400
Spacing between plants (mm)


Frequency Histogram, Field C15
Frequency of spacing occurrence (%)
50
45
40
35
30
25
20
15
10
5
0
10
30
50
70
90
110
130
150
170
190
210
230
250
270
290
310
330
350
370
390
>400
Spacing between plants (mm)

PERSONNEL

Lloyd Zyla: 100% of project time. See the expense statement under consultant's fees.

EQUIPMENT

Equipment greater than $50.00 in cost was not purchased for the project.

PROJECT DEVELOPED MATERIALS

No project materials were developed.

PROJECT PHOTOS

Slides have been taken of bean and chickpea fields, and will be provided after presentation of project results if requested.

ACKNOWLEDGEMENTS

The Saskatchewan Department of Agriculture and Food (SAF) provided funding for this project. Acknowledgement of SAF funding was given during correspondence with growers and others in the industry. Acknowledgement will also be provided during the Soils & Crops presentation and for the Saskatchewan Pulse Growers newsletter.

The work of the following people, who helped with technical input and data collection, is acknowledged and appreciated: Bert Vandenberg, Tom Warkentin, Ray McVicar, Steve Shirtliffe, Sabine Banniza, Rosalind Ball, Dorothea Barre, Stephanie McHale, Jeff Painchaud, Joelle Paradis, Veronica Smits, Michelle Wallis.

EXPENSE STATEMENT

Funds Requested	Budgeted	Actual to date*
ii) Fees – eg. Consultants	$5992.00	$5431.12
iv) Materials, supplies, telephone	$65.00	$145.66
v) Project Travel	$256.00	$736.22
Total Requested	$6313.00	$6313.00